Wet life Study of Nickel Hydrogen cells

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Background

- Unplanned launch delays often resulted in the use of batteries for NASA missions that exceed recommended wet life of 3-5 years
- HST and Space Station cells have wet life exceeding 8 years by refurbishment
- The impact of wet life of nickel hydrogen batteries on electrical performance, nickel pre-charge, gas content and degradation of the cell components are examined in this study that is sponsored by NASA-NESC

Technical Approach

Cell Analysis

[1] DPA of nickel hydrogen cells with varying wet life

DPA

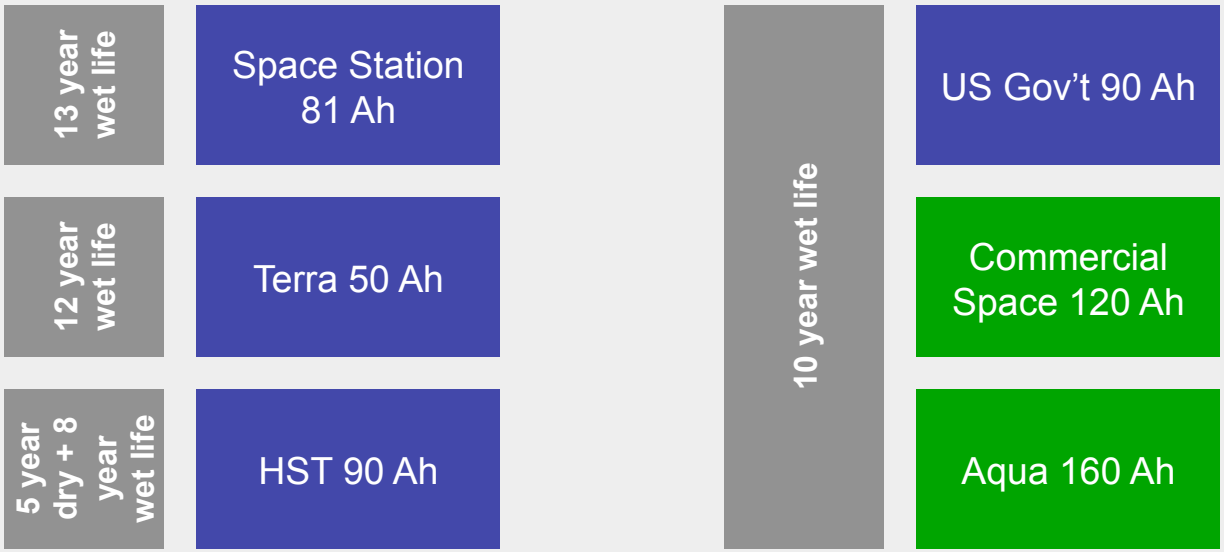
- Contract awarded to Lockheed Martin-COMSAT to perform the DPA in July 2007
- Selected 26 cells with 7-13 years of wet life from the satellites listed below:

3.5” DIA Cells		4.5” DIA Cells	
Terra 50 Ah	HST 90 Ah	Commercial Space 120 Ah	Aqua 160 Ah
US Gov’t 90 Ah	Space Station 81 Ah		

- All selected cells were in cold storage after ATP testing

Capacity

- Capacity not affected by storage as shown by:

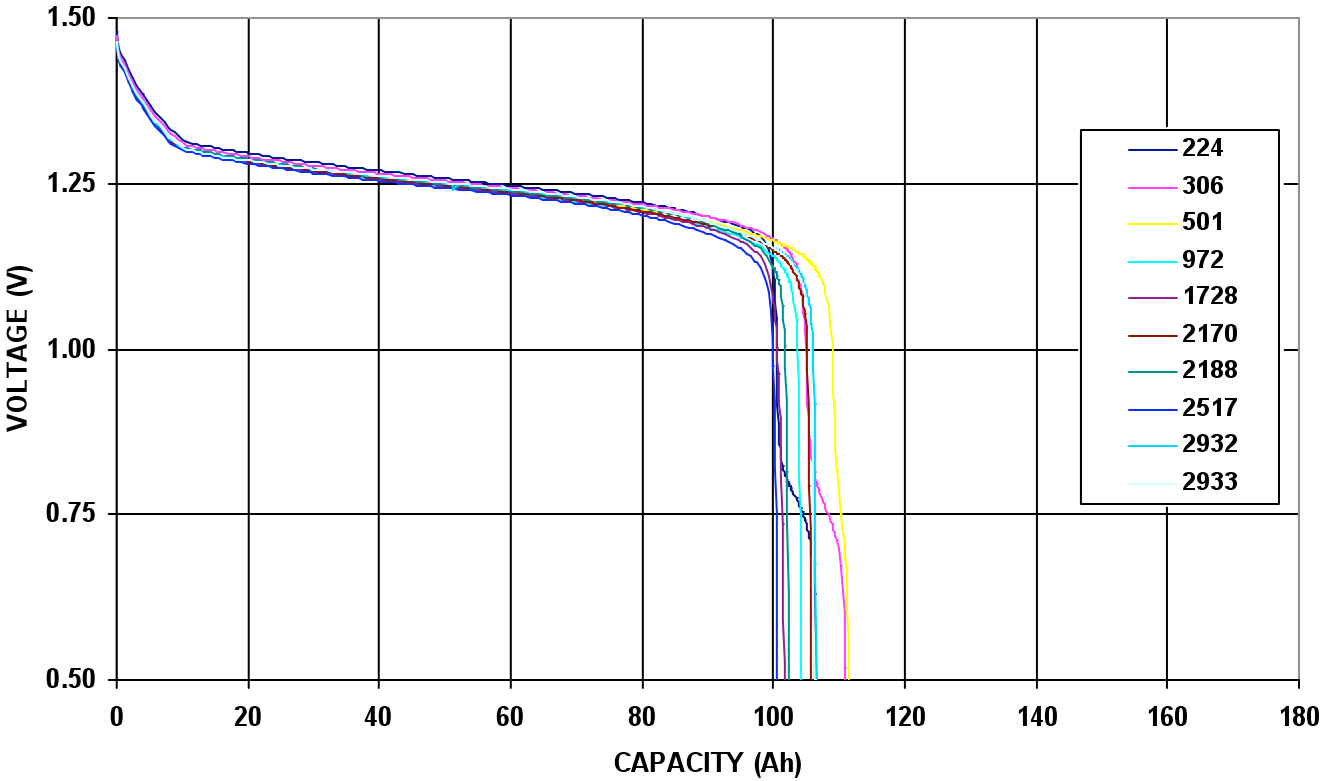


Performance Data

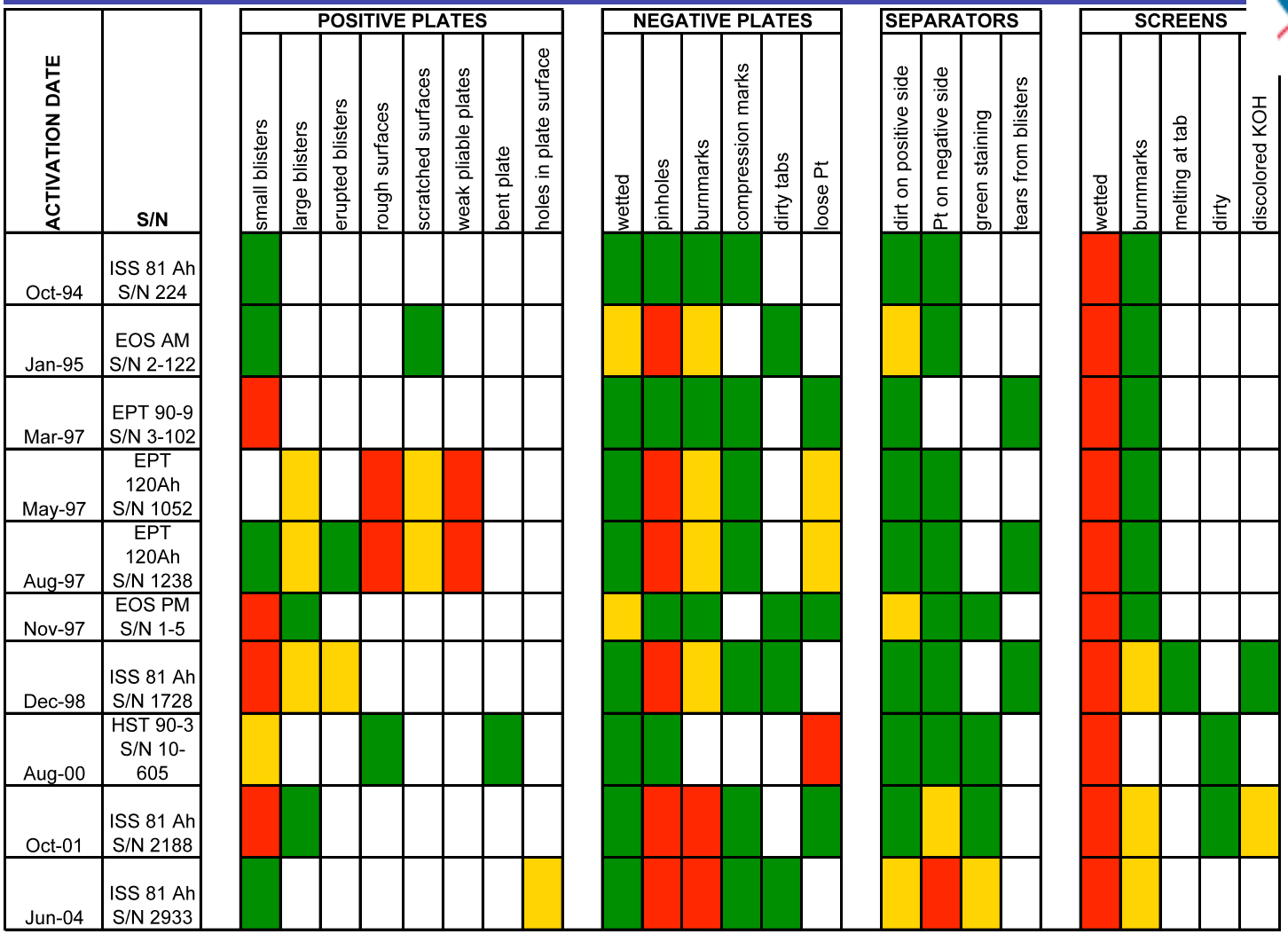
	Activation Date	S/N	10 °C CAPACITY DATA to 1 V (Ah)	2nd plateau (%)	Resistor (Ah)	Charge Retention (%)	Reversal voltage	Voltage rise after 1 hr[1]
Terra 50 Ah	Jan-1995	122(3.5")	66.9	NA	1.1	90.3	-0.28	0.095
	Jan-1996	262(3.5")	64.7	NA	1.3	90.5	-0.29	0.084
Space Station 81 Ah	Oct-1994	224(3.5")	100.5	5.5	8.0	85.9	-1.43	0.134
	Apr-1995	306(3.5")	104.9	5.5	2.3	87.6	-0.78	0.121
	Oct-1996	501(3.5")	109.0	2.2	1.1	84.7	-0.37	0.165
	Jul-1997	972(3.5")	103.6	NA	1.4	88.8	-0.31	0.110
	Dec-1998	1728(3.5")	100.6	NA	3.5	89.8	-0.33	0.091
	Jan-2000	2170(3.5")	105.1	NA	1.2	88.9	-0.32	0.086
	Oct-2001	2188(3.5")	101.7	NA	1.2	88.9	-0.32	0.134
	Aug-2002	2517(3.5")	100.0	NA	1.0	88.5	-0.3	0.095
	Jun-2004	2932(3.5")	106.0	NA	1.4	88.6	-0.31	0.084
	Jun-2004	2933(3.5")	105.6	NA	1.1	88.7	-0.31	0.105
US Gov't 90 Ah	Mar-1997	102(3.5")	103.3	NA	0.6	87.2	-0.38	0.080
	Mar-1997	165(3.5")	102.0	NA	0.7	87.3	-0.36	0.078
HST 90 Ah	Aug-2000	605(3.5")	94.7	9.2	3.8	82.2	-1.52	0.061
	Aug-2000	718(3.5")	95.1	9.1	3.5	84.6	-1.51	0.080
Commercial Space 120 Ah	Apr-1997	1038(4.5")	153.2	NA	1.5	87.9	-0.41	0.063
	May-1997	1052(4.5"	147.9	4.3	7.2	86.7	-1.53	0.060
	Aug-1997	1238(4.5")	151.2	NA	1.7	87.3	-0.42	0.089
	Aug-1999	1997(4.5")	139.9	NA	19.1	85.1	-1.23	0.072
	Feb-2000	2204(4.5")	146.1	NA	1.3	87.3	-0.36	0.108
	Feb-2004	2749(4.5")	139.8	NA	1.0	87.3	-0.33	0.091
	Aug-2006	2925(4.5")	143.4	NA	3.1	87.1	-0.32	0.130
Aqua 160 Ah	Nov-1997	5(4.5")	200.8	NA	3.1	85.5	-0.39	0.018
	Nov-1997	89(4.5")	200.8	NA	3.4	84.2	-0.4	0.016
	Nov-1997	15(4.5")	193.6	NA	1.8	87.7	-0.33	0.015

[1] After resistor drain to 10 mV

10°C Discharge Profiles for ISS 81 Ah Cells



DPA Findings of All Cells



Voltage and gas analysis (mV)

Date	S/N	after 1 hr	after 24 hr	**Gas on opening**
Jan-1995	122	0.015	0.069	No gas
Oct-1994	224	0.029	0.077	No gas
Oct-1996	501	0.034	0.062	No gas
Jul-1997	972	0.028	0.080	No gas
Dec-1998	1728	0.022	0.075	No gas
Oct-2001	2188	0.027	0.083	No gas
Aug-2002	2517	0.022	0.077	No gas
Jun-2004	2933	0.025	0.089	No gas
Mar-1997	102	0.022	0.064	No gas
Aug-2000	605	0.022	0.031	No gas
May-1997	1052	0.017	0.122	No gas
Aug-1997	1238	0.020	0.116	No gas
Feb-2004	2749	0.022	0.159	No gas
Aug-2006	2925	0.025	0.159	No gas
Nov-1997	5	0.017	0.033	No gas

[1] After resistor drain to 2 mV

Electrolyte Distribution

Activation Date	S/N	Cell Size (Ah)	Pos.Plate (g/g plate)	Neg Plate (g/g plate)	Zircar (g/g sep)	Screen (g/g scrn)
Oct-94	**224**	**81**	**0.14**	**0.04**	**1.28**	**0.08**
Jan-95	**2-122**	**50**	**0.14**	**0.05**	**1.42**	**0.12**
Mar-97	3-102	90	0.14	0.04	1.38	0.07
May-97	1052	120	0.18	0.04	1.08	0.14
Nov-97	1-5	160	0.15	0.06	1.74	0.31
Dec-98	**1728**	**81**	**0.14**	**0.03**	**1.35**	**0.20**
Aug-00	10-605	90	0.15	0.05	1.31	0.05
Oct-01	**2188**	**81**	0.15	0.03	1.29	0.28
Jun-04	**2933**	**81**	0.13	0.03	1.24	0.15

Electrolyte Concentration

Activation Date	S/N	Cell Size (Ah)	KOH Conc. (%)	K2CO3 Conc. (%)	cc/Ah
Oct-94	**224**	**81**	**28.5**	**5.1**	**3.03**
Jan-95	**2-122**	**50**	**29.7**	**3.3**	**3.39**
Mar-97	3-102	90	29.6	2.8	**2.38**
May-97	**1052**	**120**	**27.1**	**4.7**	**2.82**
Aug-97	**1238**	**120**	**25.6**	**6.4**	**2.56**
Nov-97	1-5	160	28.4	3.4	**3.73**
Dec-98	**1728**	**81**	**28.1**	**3.9**	**3.21**
Aug-00	10-605	90	30.7	2.9	**2.92**
Oct-01	**2188**	**81**	**28.0**	**4.0**	**3.18**
Jun-04	**2933**	**81**	**28.8**	**4.0**	**2.99**

Separator Characterization

Act. Date	S/N	Cell Size (Ah)	Average		Resistivity(Ωcm)		Absorbency (g KOH/g sep)
			Weight (g)	Thickness (mm)	single layer	double layer	
1992	virgin	3.5"	1.15	0.302	3.2	2.5	2.0
Oct-94	224	81	1.01	0.242	3.0	2.8	2.8
Jan-95	2-122	50	1.05	0.271	1.4	3.1	2.9
Mar-97	3-102	90	1.03	0.267	1.2	1.8	2.7
May-97	1052	120	1.94	0.258	3.2	2.6	3.1
Aug-97	1238	120	1.83	0.274	2.7	2.5	2.6
Nov-97	1-5	160	1.93	0.272	3.5	2.8	2.6
Dec-98	1728	81	1.11	0.268	3.2	2.3	2.5
Feb-00	2204	120	1.77	0.260	2.3	2.6	2.5
Aug-00	10-605	90	1.03	0.269	1.2	1.2	2.5
Oct-01	2188	81	1.03	0.248	2.6	3.7	2.5
Jun-04	2933	81	1.05	0.255	2.8	3.1	3.0

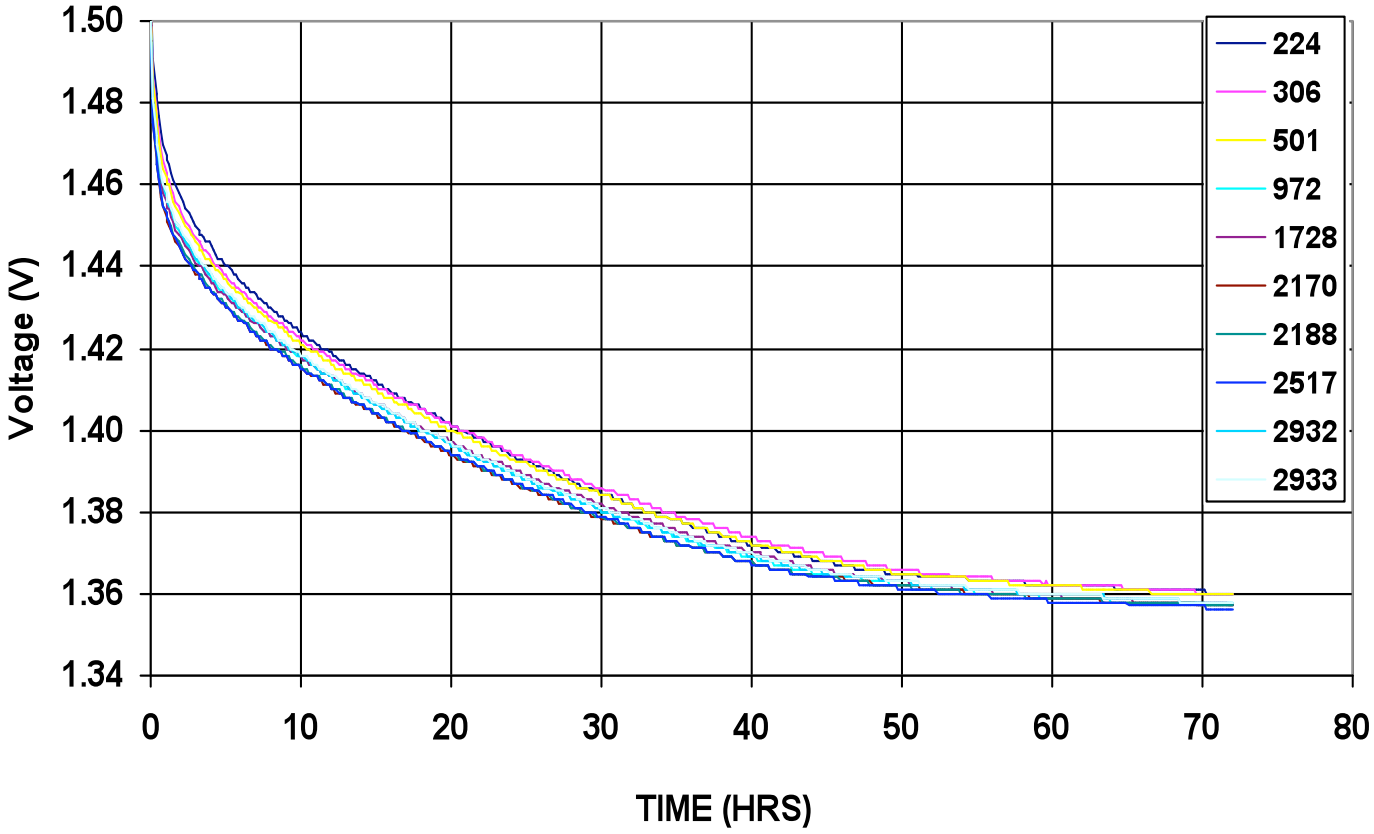
Positive Plate Analysis Comparison

Activation Date	Identification	Cell Ave. Weight (mm)	Cell Ave. Thickness (mm)	Ni(OH)2 (%,g)	Co(OH)2 (%,g)	Co(OH)2 (%,g)	Sinter (%,g)	Substrate (%,g)	POROSITY		LOADING		UTILIZATION	
									Sinter (%)	Plaque (%)	Ni (g/cc)	Total (g/cc)	Plate (%)	Cell (%)
1995	Virgin 50 AH AM lot 2	13.05	0.77	33.19 4.33	2.02 0.26	5.66	48.64 6.34	13.15 1.71	80.36	75.81	1.48	1.71	121.60	NA
1997	Virgin HST Lot 11	15.28	0.93	36.68 5.53	2.39 0.36	6.11	46.46 7.00	11.34 1.71	82.29	78.50	1.51	1.74	106.30	NA
Oct-94	S/N224 ISS 81 Ah		0.81	34.49 4.68	1.93 0.26	5.26 6.17	45.43 6.17	12.63 1.71	82.21	78.33	1.78	1.78	131.60	120.57
Jan-95	S/N 2-122 50Ah	13.58	0.81	34.05 4.65	2.58 0.35	7.00	56.49 7.72	12.55 1.71	77.56	73.88	1.67	1.67	148.10	132.30
Mar-97	S/N 3-102 90 Ah	15.65	0.95	39.69 6.26	2.43 0.38	5.72	50.45 7.95	10.87 1.71	80.48	77.23	1.80	1.80	113.90	118.95
Dec-98	S/N 1728 ISS 81 Ah	13.59	0.80	33.95 4.61	2.07 0.28	5.73	47.19 6.41	12.61 1.71	81.20	77.30	1.49	1.76	145.50	125.10
Aug-00	S/N 10-605 HST	15.49	0.94	34.76 5.31	2.46 0.37	6.51	51.66 7.88	11.23 1.71	80.57	77.30	1.44	1.54	128.50	126.95
Oct-01	S/N 188 ISS 81 Ah	13.44	0.81	33.89 4.56	2.20 0.30	6.17	46.24 6.22	12.75 1.71	82.00	78.10	1.43	1.73	153.40	129.90
Jun-04	S/N 2933 ISS 81 Ah	13.47	0.79	34.18 4.60	2.34 0.32	6.50	46.25 6.23	12.73 1.71	81.50	77.50	1.50	1.80	151.10	131.00
Nov-97	S/N 1-5 160Ah	23.28	0.83	30.68 7.15	2.24 0.33	4.41	54.66 12.74	14.33 3.34	77.97	73.71	1.41	1.43	171.70	152.00

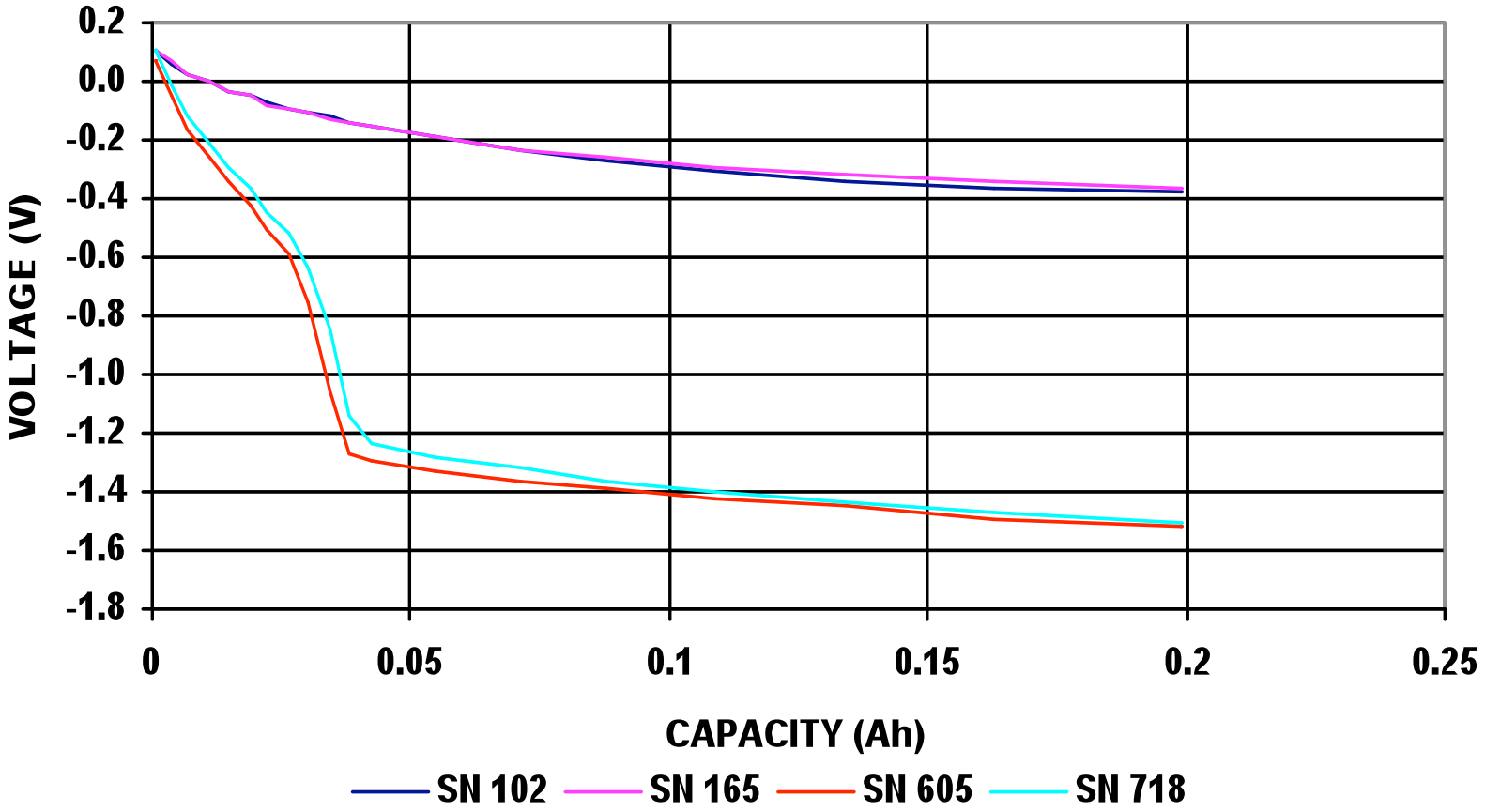
Positive Pre-charge

Activation	CELL ID	CELL CAPACITY		PRECHARGE CAPACITY		
		Rated Ah	Actual 20 °C Ah to 1.0 V	Electrical Ah	Chemical Ah	Total Ah
Oct-94	224	81	90.6	0.1	8.3	8.4
Jan-95	2-122	50	58.9	1.1	9.6	10.7
Mar-97	3-102	90	91.5	0.5	8.3	8.8
May-97	1052	120	130	0.2	14.4	14.6
Aug-97	1238	120	134.7	0.9	17.9	18.8
Nov-97	1-5	160	171.4	1.1	22.0	23.1
Dec-98	1728	81	89.7	3.0	13.6	16.6
Feb-00	2204	120	130.1	0.5	17.2	17.7
Aug-00	10-605	90	82.4	0.2	9.7	9.9
Oct-01	2188	81	90.8	2.7	10.0	12.7
Jun-04	2933	81	94.4	1.9	14.4	16.3

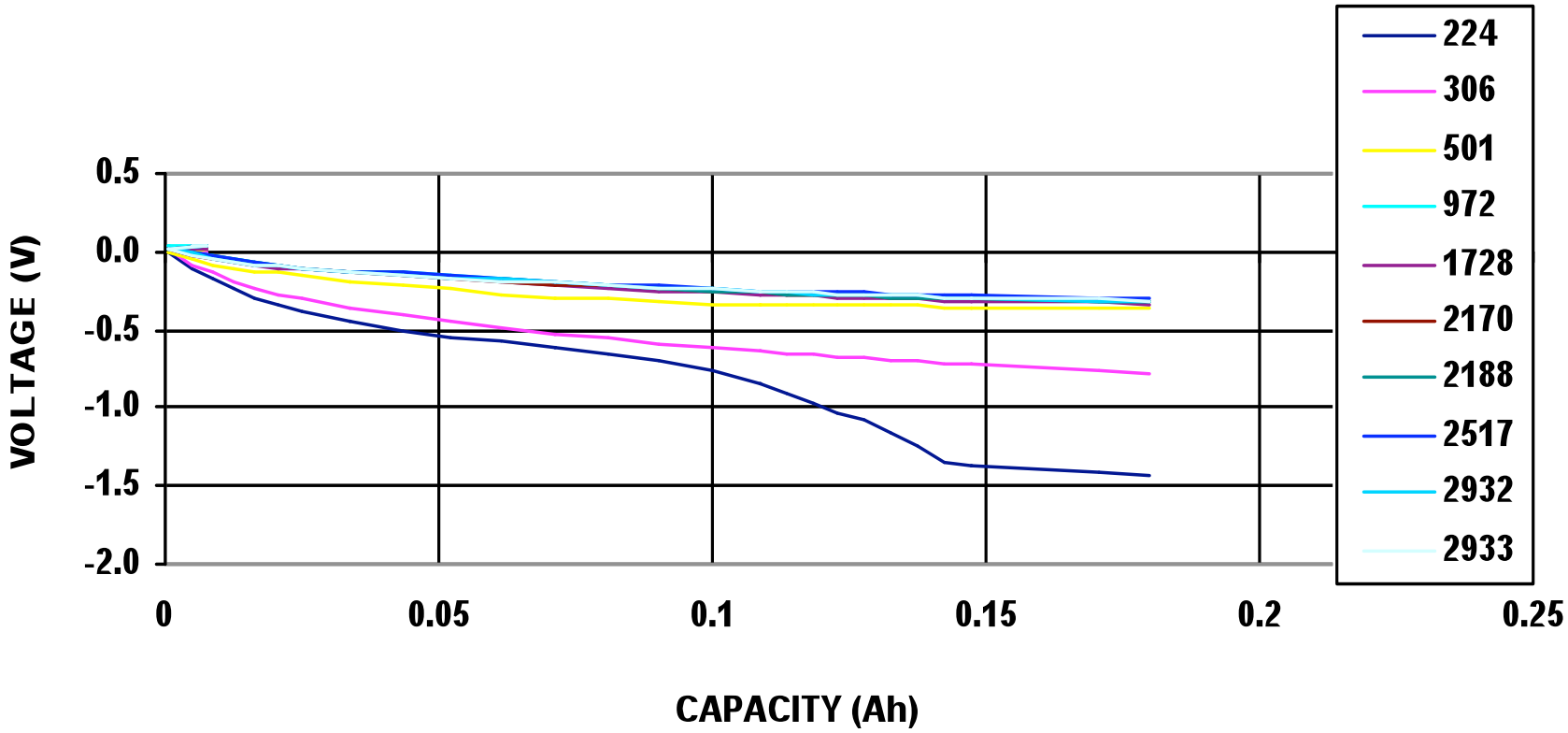
Charge Retention 72 Hour Open Circuit Stand, ISS cells



Cell Reversal for HST and US Gov't 90 Ah Cells



Cell Reversal for ISS Cells



Conclusions

- Cell capacity, charge retention, and voltage rise are not influenced by the wet life of cells
- Second voltage plateau occurs in cells with longer wet life
- There is no obvious impact of wet life on blistering of the positive plates
- Coefficient of positive material utilization is unchanged
- Wet life up to 13 years maintains nickel pre-charge and performance

Acknowledgements

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